

Uninformed sacrifice: evidence against long-range alarm transmission in foraging ants exposed to a localized perturbation

F. Tejera, A. Reyes and E. Altshuler*

Physics Faculty, "Henri Poincaré" Group of Complex Systems, University of Havana, Cuba

Abstract

It is well established that danger information can be transmitted by ants through relatively small distances, provoking either a state of alarm when they move away from potentially dangerous stimulus, or charge toward it aggressively. There is almost no knowledge if danger information can be transmitted along large distances. In this paper, we perturb leaf cutting ants of the species *Atta insularis* while they forage in their natural environment at a certain point of the foraging line, so ants make a "U" turn to escape from the danger zone and go back to the nest. Our results strongly suggest that those ants do not transmit "danger information" to other nestmates marching towards the danger area. The individualistic behavior of the ants returning from the danger zone results in a depression of the foraging activity due to the systematic sacrifice of non-informed individuals.

PACS number: Ecology, 87.23.-n; Nonlinear dynamical systems, 05.45.-a; Self-organization, complex systems, 89.75.Fb

1 Introduction

One of the most amazing features of many species of ants is the emergence of foraging lines that may span hundreds of meters from the nest to the feeding sources [1]. Such large structures are particularly vulnerable, and the ability to balance risk of death vs. value of food can provide a competitive advantage to the colony. Unlike solitary animals, ants collect food not only for their own consumption, but for the maintenance of the entire colony as well [2, 3]. In fact, the death of a worker (of many workers) is not the end of reproduction and therefore it has been viewed as a cost that the society is willing to pay [4]. But how many ants the colony can afford to sacrifice? How

foraging ants react collectively to a source of danger? These and other related questions have been rarely addressed quantitatively in the literature [5, 6, 7].

A subject intimately linked to the matter is the transmission of danger warning signals from informed to non-informed individuals. Danger information is known to be transmitted at short distances –i.e, a few ant body lengths– outside the nest by short-lived pheromone emissions, body touching or even vibrations. It may result in either a state of alarm when ants move away from potentially dangerous stimulus, or charge toward it aggressively [2]. However, little is known about the ability of ants to transmit danger information along large distances – for example, from a certain point in the foraging line to the nest, located a few meters apart.

We have approached the problem by abducting leaf-cutter ants from the species *Atta insularis* at a given point of the foraging trail in natural conditions, and quantifying "long-range" effects on several parameters of the foraging traffic in space and time. In our experiments, approximately 50 percent of the ants are abducted at a certain region of the foraging trail, and the rest are able to avoid abduction: they make a "U" turn (U-turn), and move back to the nest. Our results suggest that those ants do not transmit danger information to nestmates moving towards the abduction zone, so the overall effect on the colony is that individuals are systematically sacrificed in the attempt to maintain the foraging activity.

2 Materials and Methods

Experiments were conducted on two colonies of the Cuban leaf-cutting ant *Atta insularis*. The nests (that had not been artificially modified in any way before our experiments) were located under the pavement of one parking lot at the University of Havana. Workers foraged every night on a garden located some 150 meters from the nest. The experiments were performed between the 22:00 and the 23:00 hours, corresponding to the peak of activity of the ants in its steady state, in which the

*Correspondence to: ealtshuler@fisica.uh.cu

number of ants coming in and out of the nest per unit time are equal and constant [9, 8]. Fig. 1 shows our experimental setup: the nest’s door is to the left, and the foraging trail extends to the right. Two video cameras were used: Camera 1 was near the door, immediately to its right. Camera 2 was 3 meters to the right of the door. During our experiments, two interwoven lanes of ants were established: an *out-bound* one of ants moving from the nest to the foraging area, and another of *nest-bound* ants returning from the foraging area to the nest.

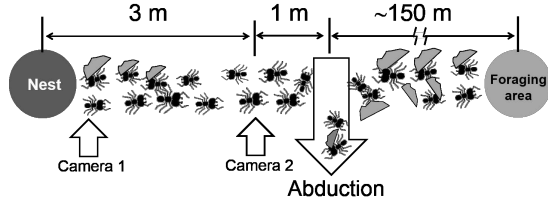


Figure 1: **Sketch of the experimental setup.** Camera 1 is near the nest’s door, Camera 2 is 3 m to the right of Camera 1, and the abduction zone is 1 m to the right of Camera 2.

In a typical experiment, the unperturbed trail was filmed by the two cameras for 25 minutes (this served as a baseline for stationary activity). Then, we abducted ants using a vacuum cleaner in an area of approximately 50 cm² located 1 m to the right of camera 2 (see Fig. 1) either for 15, 25 or 30 minutes. The outbound ants coming from the left that managed to escape from abduction simply returned to the nest, while ants coming from the right could not cross the abduction area to the left. After the abduction period, cameras 1 and 2 filmed the activity for another 20 minutes. Finally, ants were returned to their natural environment, where they behaved normally. Notice that perturbing by abduction has the advantage to “isolate” from the rest of the trail a section between the nest door and the abduction area, which facilitates the quantitative analysis of the data taken by Cameras 1 and 2, as we will see.

3 Results

Direct visual inspection and video analysis *a posteriori* showed that most outbound ants reached the abduction area. There, 50 percent of the ants were abducted (i.e., sucked by the vacuum cleaner). The other 50 percent stopped for a few seconds rising and moving the antennae in the air, and then escaped the danger after performing a U-turn to the nest. In spite

of the fact that they established numerous antennal contacts with the out-bound nestmates moving in the direction of the abduction area, the latter did not performed U-turns before reaching the abduction area.

That observation was corroborated quantitatively by measuring the out-bound ant flows at cameras 1 and 2 and comparing them: Fig. 2 (a,b) illustrates the results for one experiment. In order to estimate how many ants passed by camera 2 ($f_{C2}(t)$), relative to the total number of ants that passed by camera 1 ($f_{C1}(t)$), we determined the differences between the two flows. We smoothed out the ants flows by averaging every 300 points and take the difference as $f_{C2}(t) - f_{C1}(t - \tau)$. Here τ represents the *delay between the flows* ($\tau = 1.5$ min for the experiment we are discussing here, which correspond to the expected time an average ant moving at approximately 3 cm/s must walk to cover a distance of 3 m). The fact that the difference between the flows (Fig. 2 (b)) during the abduction time is small and similar to the average background before and after abduction corroborates quantitatively the direct visual observation that no U-turns are *induced* on the outbound ants by individuals returning from the abduction zone. We also measured the Nest-bound and Out-bound ants passing by Camera 1.

Finally, we determined the temporal spacing between ants (or waiting times [6, 10, 11]). This parameter is defined as the difference of passage time between an ant (i) and its nearest nestmate ($i + 1$): $\Delta t = t_{i+1} - t_i$. The results are displayed in Figs. 2 (d-h), and suggest that the “kinetics” of ants traffic far from the abduction zone is not perturbed by the abduction process.

4 Discussion

As described before, when a typical out-bound ant reaches the abduction zone, it may follow two fates: (a) being abducted or (b) escaping after sensing danger. Choice (b) implies that the ants make a U-turn at the abduction zone, and return to the nest. The returning ants make many antennal contacts with their out-bound nest mates. If the swarm acts collectively, it should be assumed that danger information is spread through many foragers (perhaps through chemicals [12] or just by detecting a “worrying” decrease in the number of ants returning to the nest just by counting antennal contacts). Those danger signals would induce U-turns in the out-bound ants *before* reaching the abduction zone, then increasing dramatically their survival probabilities. We will call this the Cooperative hypothesis.

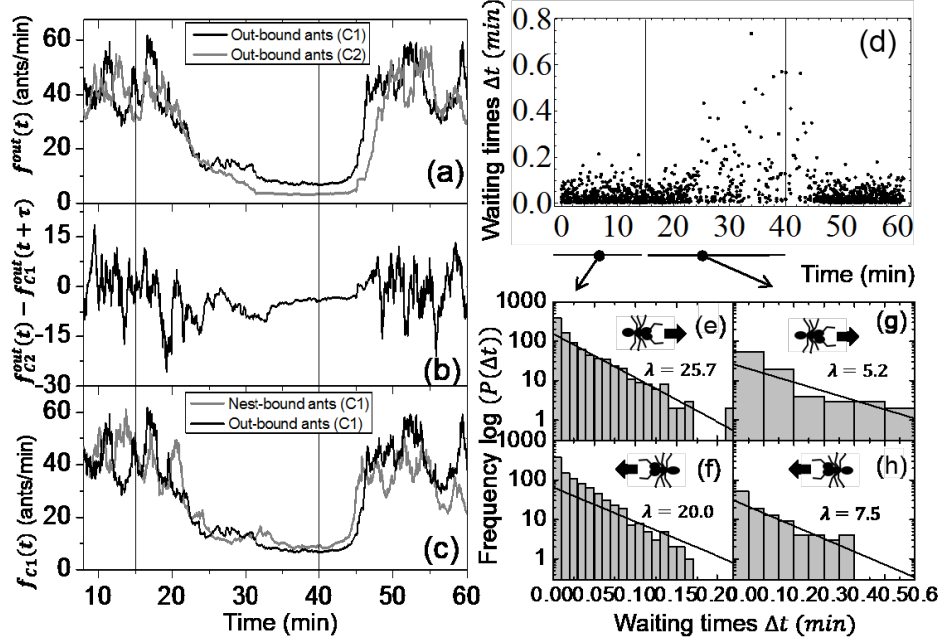


Figure 2: **Ants flows and waiting times distributions for an abduction time of 25 min.** (a) Out-bound ants flow at Cameras 1 and 2. (b) Difference between the two curves shown in (a). (c) Out-bound ants flow and Nest-bound ants at Camera 1. (d) Waiting times between passage of consecutive out-bound ants, at Camera 1. (e) and (f) Out-bound and Nest-bound waiting times distributions before abduction, respectively. (g) and (h) Out-bound and Nest-bound waiting times during the last 10 min of abduction, respectively. The two vertical lines in (a) - (d) indicate the abduction period.

In Fig. 2 we can see that the flow of ants emerging from camera 1 is slightly bigger than the flow passing by camera 2 (in normal conditions, some out-bound ants perform U-turns independent of any perturbations in order to “reinforce” the foraging pheromone track [13]). However, Fig. 2 (b) shows that U-turning remains constant and within the same range of values throughout the whole experiment as compared to background fluctuations, *including the abduction period* (averaged over different experiments, $\Delta f = \langle f_{C1}^{out}(t) - f_{C2}^{out}(t - \tau) \rangle_{no-abd} - \langle f_{C1}^{out}(t) - f_{C2}^{out}(t - \tau) \rangle_{abd} = -3.48 \text{ ants/min} \pm 4.65 \text{ ants/min}$, which is smaller than the fluctuations in Δf : $\Delta f_{rms} = 5.97 \text{ ants/min} \pm 1.44 \text{ ants/min}$, where “abd” means “during the abduction period”, “no-abd” means “out of the abduction period”, and “out” means “outbound”). Since the total number of out-bound ants between the two cameras is conserved, we conclude that there is not an increment of U-turns during the abduction period. Then, we reject the Cooperative hypothesis: our ants act individually against danger, at least on a large scale (i.e., at least

more than 1 m away from the abduction area).

Let us briefly de-tour from the subject of cooperation to find out if ants keep a long memory of danger. A large number of ants returning to the nest have directly experienced danger at the abduction zone. One might expect that these individuals should stay into the nest for a relatively long period, as an individualistic protection mechanism. Our results suggest the opposite. If we analyze the flow of nest-bound and out-bound ants seen by camera 1 (Fig. 2 (c)), we notice that the graphs are very similar and the correlation coefficient between these two flow is 0.86 ± 0.05 , for all the experiments. It indicates that there is not a significant amount of ants that decide to remain inside the nest for a longer time than usual because of the danger. This result suggests that *foraging ants do not memorize danger information, at least for a period of time longer than a few minutes.*

The distributions of waiting times for the out-bound and nest-bound ants, can be described by a Poisson process, i.e. by exponential distributions $P(t) = e^{-\lambda t}$. Figs. 2 (e-h) show the histograms for

the waiting times (including ants moving in both directions), fitted to exponential distributions. Before the kidnapping the distributions for the nest-bound and out-bound ants in both experiments are very similar, indicating that the activity is stationary. During the abduction we reduced the density of ants on the line, so we see longer waiting times for the nest-bound and out-bound ants, implying a smaller slope of the distribution (plotted in a log-linear graph). The distribution of waiting times during the abduction for nest-bound and out-bound ants, are also very similar (see Fig. 2 (g) and (h)) indicating no substantial changes in the traffic between nest-bound and out-bound ants. This provides extra evidence supporting our previous conclusions: *ants do not keep a memory record of danger, and do not share danger information with their nestmates.*

Finally, we underline some limitations of our experiments. (a) We cannot check if ants escaping from a direct abduction attempt do transmit danger information to the ones moving from the nest to the abduction area, but *those ants do not use that information to perform U-turns to avoid danger*: metaphorically speaking, we do not know if ants just don't believe in "conspiracy theory". (b) We have only probed the "long-range" consequences of possible transmission of danger information: in principle, such information may be transmitted locally (i.e., near the abduction area) *but* with no effect on the overall foraging dynamics. (c) Similar experiments during the *initial* foraging stage, or perturbing the nest near its door could provoke a different collective response. This may also happen using "stronger" perturbations like a chemical repellent [14] or heating [15].

5 Conclusions

We have performed experiments where foraging ants are abducted at a specific location of the foraging trail. Our results indicate that:

1. Ants directly facing an abduction attempt that are able to escape from it, perform a U-turn, and head back to the nest.
2. Ants escaping a direct abduction attempt act individualistically: they do not transmit danger information along large distances, potentially useful to save the lives of ants moving towards the danger zone by means of U-turns, or to recruit ants from the nest in order to fight the external threat
3. Conclusions 1-3 suggest that, in the presence of a spatially and temporally confined danger, there

is not long-range transmission of danger information, resulting in a "collective attempt" to keep the foraging activity, even at the cost of many individuals

Acknowledgements

We acknowledge support by K. Robbie and useful discussions with S. Nicolis and M. O. Magnasco. E. A. got inspiration from the late M. Álvarez-Ponte. F. T. and A. R. acknowledge funding by the "Henri Poincaré" Group of Complex Systems E. A. acknowledges partial support through Total-ESPCI and Joliot-ESPCI ParisTech Chairs.

References

- [1] Holldobler, B. & Wilson, E. *The Ants* (SpringerVerlag, Berlin, 1990).
- [2] Wilson, E. & Holldobler, B. Eusociality: Origin and consequences. *PNAS* **102**, 13367–13371 (2005).
- [3] Boomsma, J. & Franks, N. R. Social insects: from selfish genes to self organisation and beyond. *TRENDS in Ecology and Evolution* **21**, 303–308 (2006).
- [4] Bourke, A. F. G. Social Evolution : Daily Self-Sacrifice by Worker Ants. *Current Biology* **18**, 1100–1101 (2008). URL <http://dx.doi.org/10.1016/j.cub.2008.10.016>.
- [5] Halley, J. D. & Elgar, M. A. The response of foraging Argentine ants, *Linepithema humile*, to disturbance. *Aus. J. Zool.* **49**, 59–61 (2001).
- [6] Richardson, T. O. *et al.* Record Dynamics in Ants. *PLoS ONE* **5**, 1–7 (2010).
- [7] Pinter-Wollman, N. *et al.* Harvester ants use interactions to regulate forager activation and availability. *Animal behaviour* **86**, 197–207 (2013).
- [8] Noda, C., Fernández, J., Pérez-Penichet, C. & Altshuler, E. Measuring activity in ant colonies. *Rev. Sci. Inst.* **77**, 126102 (2006).
- [9] Nicolis, S. C. *et al.* Foraging at the Edge of Chaos: Internal Clock Versus External Forcing. *Phys. Rev. Lett.* **110**, 268104 (2013).
- [10] Richardson, T. O., Christensen, K., Franks, N. R. & Jensen, H. J. Group dynamics and

record signals in the ant *Temnothorax albipennis* Group dynamics and record signals in the ant *Temnothorax albipennis* *J. R. Soc. Interface* **102**, 131–134 (2010).

- [11] John, A., Schadschneider, A., Chowdhury, D. & Nishinari, K. Trafficlike collective movement of ants on trails: absence of a jammed phase. *Phys. Rev. Lett.* **102**, 108001 (2009).
- [12] Sasaki, T., Holldobler, B., Miller, J. G. & Pratt, S. C. A context-dependent alarm signal in the ant *Temnothorax rugatulus*. *J. Exp. Biol* **75**, 3229–3236 (2014).
- [13] Evison, S., Hart, A. & Jackson, D. E. Minor workers have a major role in the maintenance of leafcutter ant pheromone trails. *Anim. Behav.* **75**, 963–969 (2008).
- [14] Altshuler, E., Ramos, O., Núñez, Y., Batista-Leyva, A. & Noda, C. Symmetry breaking in escaping ants. *Am. Nat.* **166**, 643–649 (2005).
- [15] Boari, S., Josens, R. & Parisi, D. R. Efficient Egress of Escaping Ants Stressed with Temperature. *PLoS ONE* **8**, 1–7 (2013).